UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
166 Water Street
Woods Hole, MA 02543

December 18, 2002

DRAFT

CRUISE RESULTS

NOAA Fisheries Research Vessel DELAWARE II
Cruise DE 02-08 (Parts 1 – 3)

Atlantic Herring Hydroacoustic Survey

CRUISE PERIOD AND AREA

Cruise operations were completed on the continental shelf (depths to 300 m) in the Gulf of Maine and Georges Bank regions, including the Canadian Exclusive Economic Zone on eastern Georges Bank. The 2002 Fall Atlantic Herring Hydroacoustic Survey was conducted during three parts between 3 September and 11 October 2002. The first day was allocated to acoustic calibrations dockside in Woods Hole. The FRV Delaware II departed on the second day, and conducted acoustic survey operations in the Jeffreys Ledge region during 4-13 September (Fig. 1). During part 2, a systematic survey was completed along northern Georges Bank during 17-27 September (Fig. 2). Part 3 of the cruise focused on experimental research on Georges Bank during 30 September through 11 October (Fig. 3).

OBJECTIVES

The Northeast Fisheries Science Center (NEFSC) conducts Atlantic Herring Hydroacoustic Surveys each autumn on the historical spawning grounds of Atlantic herring (*Clupea harengus*) in the Gulf of Maine and Georges Bank regions. The primary goal of these fisheries acoustic surveys is to provide improved cost-effective, timely, and accurate fisheries-independent estimates of herring spawning stock biomass using advanced technologies. Operational objectives of this year's cruise were to (1) calibrate the EK500 scientific echosounder's 18, 38, and 120 kHz transducers, (2) conduct hydroacoustic surveys of Atlantic herring (*Clupea harengus*) stocks in the Gulf of Maine and Georges Bank regions, (3) verify species-specific acoustical measurements with midwater trawl and underwater video deployments, (4) conduct *in-situ* multi-frequency target strength (TS) experiments on herring, (5) compare estimates between the EK500 and EK60 scientific echosounders, and (6) evaluate the Quester Tangent (QTC) seabed classification system.

METHODS

Survey design:

Systematic surveys were conducted on historical herring spawning grounds in the Gulf of Maine (i.e., Jeffreys Ledge) and northern Georges Bank regions during Parts 1 and 2. The survey design included a series of evenly spaced parallel transects within selected strata. The first transect within each stratum was randomly selected. A transect was defined as a portion of the cruise track with a constant vessel heading and speed, and assigned a unique sequential transect number. Survey speeds typically ranged from 8-11 knots depending on weather conditions. Fisheries acoustic data was collected continuously along the cruise track and during gear deployments using the EK500's 18, 38, and 120 kHz frequencies. Midwater trawling, underwater video, and CTD (conductivity-temperature-depth) deployments were routinely conducted to identify species composition of backscatter, collect biological data, and document hydrographic conditions. Biological samples were collected and processed using standard NEFSC procedures. Trawl catch, event logging, navigational, oceanographic, and meteorological data were recorded using the FRV Delaware’s onboard Fisheries Scientific Computer System (FSCS).

Experimental research:

EK500 operations were conducted along experimental transects in the northern Georges Bank region during Part 3 to collect volume backscatter and individual target strength (TS) measurements on Atlantic herring and other pelagic species (e.g., redfish). Day-night comparisons were made to investigate the diurnal variability in their acoustic measurements. Midwater trawling, underwater video, and CTD were conducted intermittently during the experiments. Comparisons were also conducted between the EK500's and EK60's 38 and 120 kHz data. The Quester Tangent (QTC) Impact Seabed Classification System (v..3.00) was tested and evaluated during the end of the cruise, while underwater video provided observations on substrate type.

EK500 Scientific Echosounder:

Fisheries acoustics is internationally accepted as an effective technology for surveying and estimating the populations of pelagic fish such as herring, provided data is collected by a calibrated scientific grade echosounder. A calibrated Simrad EK500 Scientific Sounder System (v.5.30) was used during the cruise. The EK500 provides low self-noise, high transmit power, instantaneous dynamic range of 160 dB, unlimited range compensation (TVG), and efficient transducers for scientific-grade detection capabilities for fisheries research and assessment. The FRV Delaware’s EK500 operated three hull-mounted transducers (split-beam 18, 38, and 120 kHz) continuously along transects and during gear deployments. EK500 data were collected simultaneously from each of the three frequencies throughout the cruise at a ping rate of every two seconds. An EK500 operational eventlog was maintained throughout the cruise using an Eventlog program and hand-written logs.

The EK500 vertically echo-integrated the volume backscatter estimates (Sv in units of m^2/m^3) into 0.5 m depth increments. Volume backscatter were converted to cross-sectional backscatter (Sa in units of m^2/nm^2) as a relative index of abundance along the cruise track. Individual target strength (TS) measurements were also collected by the EK500. EK500 data were logged to the vessel's PC server using SonarData's EchoLog program (v.2.25.15) via TCP/IP ETHERNET line. The EK500 received its navigational input from the vessel's Scientific Computer System (SCS) differential GPS output. Preliminary post-processing of the EK500 data was conducted at sea using the Echoview software (v.2.25.60) to filter unwanted noise and partition species-specific backscatter.

EK500 Calibration:

The EK500 was calibrated using the standard sphere calibration procedure before conducting survey operations. For each frequency, a calibration sphere of known target strength was suspended under the hull-mounted transducer. The calibration sphere was moved throughout the beam pattern using three remotely controlled downriggers. TS gain and angle offset parameters for the 18, 38 and 120 kHz split-beam transducers were derived using the Simrad Lobe program (v.95.01.17). Sv gain was verified based on the integration tables. Existing survey parameters for the transducers typically remain unchanged given high precision and agreement with previous calibration results. Ambient noise tests were conducted to ensure there were no cross-interference between acoustical instrumentation. The amplitude from the transceiver test menu was checked routinely before, during, and after each cruise to ensure the EK500 system was operating properly during survey operations.

High Speed Midwater Rope Trawl (HSMRT):

The High Speed Midwater Rope Trawl (HSMRT, Gourock design R2028825A) was deployed intermittently to sample acoustic backscatter to verify species composition and collect biological samples. The HSMRT is a four seam pelagic trawl designed with 53.1 m headrope, footrope, and breastlines. Reduced meshes in the wings allow the trawl to be towed at high speeds. The HSMRT was towed at speeds ranging from 3.8 - 5.0 knots, with average tow speeds of 4.5 knots. The HSMRT was rigged to 1.8 m^2 double-foiled Suberkrub-type doors with 62.4 m of upper and lower bridles. An optimum tow configuration using 2.5 m setback, 272 kg tomweights, and intermediate door spread with two shoe weights per door was implemented during the cruise. The mouth opening of the HSMRT averaged approximately 13 ± 3 m vertical and 27 ± 5 m horizontal. Trawl duration, tow depths, and tow speeds were not standardized or consistent between trawls, therefore trawl catch data is not recommended for abundance estimates. The mid-water trawl is generally deployed to specific depths based on the acoustic backscattering layers observed from the real-time displays of the EK500 echosounder and FS903 trawl monitoring sonar systems. The tow profile of the trawl was typically dropped incrementally through the water column to the desired depth of the scattering layer or about 10 m off the bottom, held at that depth until an adequate sample is obtained according to the FS903 display, and then retrieved back to the surface. Tow duration varied between 10 to 60 minutes depending on acoustic fish signals observed. Tow duration was defined as the time between setting the doors in the water to when doors were hauled out of the water.

Midwater Trawl Monitoring:

Midwater trawl performance was measured with a FS903 system, ITI system, and a pair of Vemco temperature-depth Minilog sensors. The Simrad FS903 Trawl Monitoring System is a third-wire device that provided real-time sonar images of the trawl opening and performance. The FS903 sonar display also showed whether fish were passing into or around the trawl opening, thus allowing the tow duration to be minimized to capture only the necessary amount of herring required for scientific samples. The Simrad ITI wireless trawl sensors were used to obtain point measurements of the trawl depth, wing spread, and door spread. Minilog depth-temperature probes were attached to the trawl headrope and footrope to provide continuous depth-temperature and trawl performance profile data for each deployment.

Biological Sampling:

The catch from each trawl was sorted by species, weighed, and measured (fork length to the nearest cm) according to standard NEFSC procedures. Additional biological sampling for Atlantic herring included individual weights (to nearest 0.1 g), fork lengths (nearest mm), stomach content analyses, and otolith samples for aging. The vessel's FSCS system was ulitized for on-board entry and auditing of navigational, catch, and biological data from trawling operations.

Static Underwater Stereo Video System:

An underwater video system designed by the NEFSC Fisheries Acoustics Research Group was used to directly verify acoustic targets. The lights, stereo video cameras, and attitude sensor is mounted to a sled-like tow-body that was deployed midship from the forward A-frame while the FRV Delaware drifted over selected backscatter aggregations. The video system is generally orientated towards the acoustic beam of the vessel's hull-mounted transducers. A pair of matched underwater video cameras were mounted in the array to obtain stereo imagery of targets. The video cameras (DSP&L Super Sea Cam T5000-B-E) have low light capability (0.001 lux sensitivity @ f 0.8) with fixed focus at a working distance from 60 cm to infinity (97^0 h x 77^0 v field of view). Two (DSP&L Multi-SeaLites DML-1090-F-B-120/100, 6000m) provided illumination that were dimmed remotely using an isolated variable transformer (120 v, 5 amp). The lights were fitted with stainless steel collars that enabled easy installation of different light filters. The real-time depth profile, pitch and roll, compass bearing, and temperature of the system were recorded every 10 seconds using the JASCO Attitude Sensor. The real-time video and environmental data were monitored and recorded through a 330 m multi-conductor cable via portable winch system to a PC computer and digital tape recorders. The stereo video recordings were time-stamped by frame with a time-code generator.

Fisheries Scientific Computer System (FSCS):

The FRV Delaware's Fisheries Scientific Computer System (FSCS) continuously collected navigational, oceanographic, and meteorological data at a rate of every 30 seconds throughout the cruise track. FSCS was also designed for on-board entry and audited of the station, catch, and biological data from trawl sampling operations. The FSCS Event Logger program was also used throughout the cruise to document operational events, such as the start and end points of times and positions of each transect and deployment. The time for all data collection through the FSCS and other computer systems were synchronized using a master GPS clock and Dimension 4 software.

Survey Design Experiment:

An experiment was conducted on northern Georges Bank to examine the variability in the acoustic populations estimates for herring using various survey designs. A stratified evenly spaced transect survey design was conducted during Part II (Fig. 1). An adaptive approach was implemented to ensure that the length of the transects included the herring aggregation (i.e., a transect did not end in an area of high fish concentration). Transects (lengths and distances between transects) were chosen to cover the

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bathymetric features which delimit each area. Each transect was sequentially numbered and defined as a continuous cruise track with a single heading and constant ship speed. Parallel transects were defined as a series of parallel coordinated vessel tracks within a specified area. Cross-over transects were tracks perpendicular to parallel transects for traveling between parallel transects, and were generally not used for abundance estimates. Midwater trawl and CTD deployments were conducted intermittently along transects to identify acoustic backscatter and oceanographic parameters. Upon completion of a deployment, the previous transect number was

resumed if the vessel continued along the track at approximately the same location and heading of the previous transect. If the vessel heading changed or the vessel did not resume near the end of the previous track, the transect number was incremented. Vessel speed during all surveys was designated at 10 knots, while actual survey speeds ranged from 8-12 knots depending on weather conditions and currents.

During Part III, a randomly selected parallel transect design was conducted in the same survey area on northern Georges Bank (Fig. 2). The next survey design implemented was a zig-zag design (Fig 2). A zig-zag design was typically used to survey an elongated area aligned with a shoreline or bathymetric contours. A zig-zag survey consists of a series of coordinated transects where the ending of the previous track and the beginning of the next track occur in the same location and the angle between transects is consistent. An advantage of a zig-zag design is the more efficient cruise track from eliminating cross-over transects, however the nodes where transects intersect must be eliminated from the population estimates.

Acoustic Data Collection and Post-Processing:

The primary acoustic data used for population estimates of Atlantic herring were collected with the Simrad EK500 scientific echosounder (v.5.30) operating three hull mounted transducers (a 12 kHz single-beam and 38 and 120 kHz split-beam transducers). The three frequencies were transmitted simultaneously at a ping rate of one ping per two seconds. EK500 data were simultaneously transmitted to a Sun Sparc 5 workstation and a PC computer for storage and post-processing. EK500 data consist of echogram data (binary files with acoustic signals vertically integrated into 0.5 m bins) and a relational INGRES database. EK500 data were post-processed on the Sun workstation using Simrad's BI500 (v.1.9.1996) post-processing package during the cruise. Post-processing included removing bottom interference from the water column signal and apportioning acoustic backscatter to species composition. Data for all three frequencies were post-processed and apportioned to herring backscatter while at sea based on midwater trawl catches, target strength distributions, and backscattering patterns of aggregations. The 38 kHz data was the primary data used for post-processing and deriving population estimates, and the 12 and 120 kHz data were post-processed identically for multifrequency analyses. After post-processing the data at sea, the EK500 data (echogram files and the INGRES database) were downloaded to a shore-based computer at NEFSC for archiving upon the completion of each cruise part. These data will be further processed at the laboratory and loaded into the NEFSC Oracle data management system. EK500 data was also logged and post-processed at sea using the SonarData EchoLog and EchoView software packages (v.1.2), and evaluate the future implementation of this new acoustic post-processor.

The EK500 processed each acoustic signal (ping) by correcting for beam pattern effects, calibration constants, and hardware gains, and then vertically integrated the data into 0.5 m bins (echogram data). Each half-meter bin is volume backscatter (s_v) with units of m^2/m^3 and is a quantitative measure of relative density. The minimum volume backscatter threshold of -66 dB (dB = 10 $\log_{10}(s_v)$) was used to remove acoustic scattering by non-swimbladdered fish, invertebrates, and zooplankton from the backscatter by swimbladdered fish (e.g., herring). For preliminary data analysis and diagnostics, volume backscatter was vertically integrated from a specified depth below

the surface ("bubble layer") to 0.5 m above the bottom. Data between the surface and the bubble layer were not included in the analysis to eliminate scattering by surface bubbles and noise. The bubble layer was set to 10 m for the 38 and 120 kHz data. The bubble layer was set to 32 m for the 12 kHz data as the upper 32 m of the 12 kHz data have significant noise from the "ring-down" of the transducer. Vertical integration of volume backscatter from the bubble layer to the bottom gives areal density estimates (s_a) with units of m^2/m^2 for all scatterers in the water column. The BI500 then scales these density estimates from m^2/m^2 to nautical mile squared ($m^2/nm^2 = s_a * 1852$ m^2/nm^2). We calculate s_a at 0.5 nautical mile intervals. s_a values are an index of relative areal density, and further analysis is required to produce numeric abundance and biomass estimates for a survey area.

Other Data: Conductivity-temperature-depth (CTD) were conducted throughout the cruise, generally at the transect nodes and locations of gear deployment. During part II of the cruise, Gerald Denny of Scientific Fisheries Incorporated (Anchorage, Alaska), conducted acoustic measurements with a broadband acoustic system. His towbody was suspended from the forward A-frame while the FR/V Delaware was drifting. Acoustic data from the broadband system was collected and analyzed using a Scientific Fisheries software package.

RESULTS

Cruise operations were divided into four tasks; calibration of the scientific echosounder, systematic survey for population estimates, in-situ experiments to investigate the variability in the estimates, and testing new acoustic instrumentation.

Departure was delayed one day due to northerly winds, therefore EK500 calibrations were conducted dockside along the Woods Hole Oceanographic Institution pier between September 5th at 23:00 and September 6th at 06:00 (all times herein are GMT). The 120 and 38 kHz split-beam transducers were accurately calibrated, but the 12 kHz single-beam transducer could not be calibrated. Transceiver settings for gains and offset parameters remained unchanged from previous surveys except for a slight modification to the Sv gain of the 120 kHz. The FR/V Delaware departed Woods Hole, MA on September 6th at 13:15 to begin Part I of the Fall 2000 Herring Acoustic Survey.

Part I Operations:

Shakedown operations and systematic surveys were conducted in the Gulf of Maine region during Part I (Fig. 1). Midwater trawl and acoustic shakedown operations were completed in the Wilkinson Basin area (around 42^{0}45'N 69^{0}52'W) between September 6 at 22:34 and September 7 at 03:12. The Jeffreys Ledge survey (transects 1 - 31) was completed between September 7 at 04:53 and September 8 at 12:24. The Platts Bank survey (transects 33 - 43) was completed between September 8 at 14:29 and 23:45. The last survey to be completed during Part I was Fippennies Ledge (transects 45 - 53) during September 9 at 01:41 - 07:49. The first four midwater trawl deployments (consecutive deployment numbers 1 - 4) were aborted due to harness and cable connection problems of the FS903 trawl monitoring system. A midwater trawl was successfully completed on Jeffreys Ledge (deployment 5) and Platts Bank (deployment 6). Some Atlantic herring were observed on Jeffreys Ledge, while aggregations of herring were not observed in the Platts Bank and Fippennies Ledge regions. An underwater video deployment (deployment 7) on Fippennies Ledge was unsuccessful due to cable wiring problems. The FRV Delaware arrived in Portland, ME on September 9 at 16:00 to exchange scientific staff.

Part II Operations:

Part II began when the FRV Delaware departed Portland, ME on September 10th at 14:00. Cashes Ledge was surveyed (transects 54 - 70) from September 10 at 22:51 to September 11 at 10:06. Midwater trawl deployment 8 on Cashes Ledge captured mostly silver hake. Some potential herring backscatter was observed on Cashes Ledge. Trawl deployment 9 was aborted due to FS903 disconnection, and trawl deployment 10 was a test tow to ensure the FS903 was operational. The Cashes Ledge survey (transects 54 - 70) was completed on September 11 at 10:07. The first systematic survey of evenly spaced parallel transects along the northern flank of Georges Bank began on September 11 at 23:19. EK500 settings were changed from a depth range of 250 m to 500 m with 1.0 m resolution. Trawl deployment 12 captured mainly silver hake and juvenile butterfish, while trawl deployment 11 was aborted due to the FS903 connection problems. The vessel intermittently stopped and drifted on aggregations of herring to collect acoustic target strength measurements with the EK500 (deployments 13, 20, 25, 29, and 33) and broadband acoustic measurements (deployments 14, 21, 26, and 30). An underwater video (deployment 15) was attempted, but aborted due to pigtail wiring problems. Conductivity-Temperature-Depth (CTD) profiles (deployments 16, 19, 22, 23, 27, and 31) were conducted at the end of selected transects and deployment sites. Midwater trawling (deployments 17, 18, 24, 28, 32, 34) confirmed that Atlantic herring was the predominant pelagic fish species in the Georges Bank survey area. The first evenly spaced parallel transect survey (transects 72 - 105) was completed on September 16 at 04:28 ending Part II.

Part III Operations:

Part III began upon departing Woods Hole, MA on September 18, and the second survey on Georges Bank using a random stratified parallel design began on September 19 at 03:06. During this survey, 33 CTD profiles (deployments 37-37, 39, 40, 42, 44-47, 49-53, 55, 56, 59-61, 63-67, 69-70, 72-74, 76-79) and 12 midwater trawls (deployments 38, 41, 43, 46, 48, 54, 57, 58, 62, 68, 71, 75) were successfully completed. The random stratified parallel survey (transects 106 - 132) was completed on September 24 at 00:16. The FRV Delaware began a zig-zag transect survey (transects 133 - 155) on September 24 at 00:50. The zig-zag survey design was completed on September 29 at 03:31.

Part IV Operations:

The FRV Delaware departed Woods Hole on October 3 to begin part IV. A systematic survey of evenly spaced parallel transects (transects 156 - 168) was repeated beginning on October 4 at 02:21 to compare intra-variability within the evenly spaced parallel transect survey design. This second survey using the evenly spaced parallel design was completed on October 6 at 17:02, and a third replicate survey (transects 169 - 181) using the same design began at 17:08. The third survey using the evenly spaced parallel transects ended on October 8 at 20:59. We began a series of night/day comparisons along an experimental transect (184 - 187) on northern Georges Bank on September 9 at 02:47. Operations were curtailed for about 20 m hours due to rough seas exceeding 2 m. The night/day comparisons (188-189) resumed on October 10 at 14:45. Rough seas once again stopped acoustic operations on October 11 at 00:40,

and the FRV Delaware slowly (5 kts) worked towards Woods Hole by conducting the final transects (190 - 191) along the 150 m contour of northern Georges Bank. The FRV Delaware arrived in Woods Hole on October 11 at 22:00, approximately 1½ days earlier than originally scheduled.

In summary, the Fall 2000 Herring Acoustic Survey successfully completed the primary objectives. Approximately 4,876 nautical miles of acoustic transects were completed in the Gulf of Maine and Georges Bank regions. Preliminary abundance estimates indicate a large biomass of herring were present along northern Georges Bank throughout the cruise period, while a relatively low biomass of herring were observed in the Gulf of Maine along our cruise track. A total of 164 gear deployments were conducted throughout the cruise, with 49 midwater trawl deployments (Table 1). The predominant pelagic fish captured was Atlantic herring, particularly in the northern Georges Bank region. Additional effort was made this year to collect salinity-temperature-depth profiles with 103 CTD deployments. More routine CTD deployments will be implemented during future acoustic surveys to investigate interannual variability in the density distributions of herring and other pelagic fish and squid in relation to environmental anomalies. Underwater video operations were unsuccessful this year due to cable/pig-tail wiring problems resulting from modifications of the platform to meet multiple objectives. The main problem occurred from a Pan-tilt AC and JASCO Attitude Sensor DC ground sharing the same conductor which caused NEMA and video interference. This wiring problem will be resolved in time for the next cruise by adopting a universal pigtail that can be used for fisheries acoustic, habitat assessment, and gear selectivity operations. There was excellent progress with experimental work with broadband acoustics during the second leg. Broadband acoustical data was collected on a variety of aggregations, including Atlantic herring. Broadband acoustics is an advanced technology under development which has the potential for increased capability to classify species-specific backscatter.

Considerable effort was devoted this year to repeating the northern Georges Bank survey using various survey designs (i.e., stratified evenly spaced parallel transects, randomly selected parallel transects, and zig-zag transects) in an effort to determine an optimal design. Preliminary results suggested that the random selected transect design had less variability than the other designs. The evenly spaced design was also repeated three times to investigate the intra-variability with a given design. The successful completion of this survey design experiment will help to provide us with confidence intervals on our future acoustic population estimates.

DISPOSITION OF DATA

All data and results are archived at the Northeast Fisheries Science Center. Results will be presented and data distribution on CD-ROM at an annual Northwest Atlantic Herring Acoustic Workshop in conjunction with scientists from the Canadian Department of Fisheries and Oceans.

SCIENTIFIC PERSONNEL

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Part 1 September 3 - 13, 2002
Part 2 September 16 - 27, 2002
Part 3 September 30 - October 11, 2002

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